Assignment2_python_template

October 12, 2024

1 Assignment 2

1.1 GEOS 300

Term 1 (Autumn 2024)

University of British Columbia

1.1.1 Instructor:

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1.2 Instructions:

It is strongly recommended that you complete this assignment in Python or R. Templates (this document) are provided for the Python programming language. You may choose to complete this assignment using other software, such as Excel, Sheets, or Numbers.

Please upload your completed assignment as a .pdf file to the course Canvas page as a single, well structured report. Include all figures, tables, graphs, code/calculations, and written answers. We recommend completing the assignment within a Jupyter Notebook document (like this one); you can add "cells" for written answers using the Markdown format for the cell. The completed notebook can then be downloaded as a .pdf file (File -> Save and Export Notebook As -> pdf), which you can upload to canvas. If you do not complete the assignment in a JupyterNotebook, please upload a separate file containing your code.

You can choose to instead write your answers in some other document processor (e.g. Word) and paste your figures, code/calculations etc., however, if you choose to do this, please ensure all your code and calculations are legible, and ensure it is clear what language/program was used to perform the calculations. Label the report document with your name, your student number, the course and year. Upload your report to Canvas by the Assignment deadline on the Canvas page. Do not attach a spreadsheet (except as a supplemental code document if you complete the assignment in Sheets/Excel/Numbers etc).

Include **correct units on all plots and all answers**, where applicable. Label all axes with the appropriate variables and units.

Points per question are indicated in square brackets. This assignment is worth 10% of the final course grade.

1.2.1 Site/data details:

dataset 1 (data20100710): This dataset contains radiation data measured on the UBC Vancovuer campus at Totem Field (49.2 ∘ N, 123.2 ∘ W). This data can be found in the file data20100710_py.csv on the Canvas webpage for this assignment. The .csv file contains the following variables: incoming and reflected short-wave radiation (K↓, K↑), incoming and outgoing longwave radiation (L↓, L↑), air temperature (Ta) and relative humidity (RH). Use this dataset to answer the remaining questions. Place the .csv file in the same folder as this .ipynb folder in your JupyterOpen file system.

dataset 2 (data20090324): The soil at the climate station has been analyzed in the lab and the following values were determined: porosity is P = 0.57, bulk density of the dry soil is s = 1.13 Mg m−3. The soil organic mass fraction was determined 3.77 % (of total dry soil mass). Assume that those values apply to the entire vertical profile.

Getting started: enter your name and student number

[11]:
```
Student_Name = 'Jeffery Liao'
Student_Number = 42174557
print(f'GEOS 300 Assignment 1 Submission for {Student_Name}: {Student_Number}')
```

```
GEOS 300 Assignment 1 Submission for Jeffery Liao: 42174557
```

We need to import python "packages" that contain useful functions for the kind of data analysis covered in this assignment.

[12]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
import datetime
from datetime import datetime as dt
import time
```

1.3 For the first several questions, we'll continue using the same dataset as in assignment 1.

[13]:
```
### First, open the dataset:

# Import the data  - upload this file from Canvas and put it in the same folder␣
↪as your assignment.
# data_file = 'GEOS300/Fall2024/Assignment1/FromSara/data/data20100710.csv'
data_file = 'data20100710_py.csv'
```

```
dateparse = lambda x: dt.strptime(x, '%Y-%m-%d %H:%M')

# Pandas (pd here) allows us to set a timestamp as an index which lets us␣
↪easily parse time series data
# It opens the csv file into a data format called a "data frame", so we're␣
↪going to call it "df" for short
df1 = pd.read_csv(data_file,parse_dates=['Date'],date_format='%Y-%m-%d %H:
↪%M',index_col=['Date'])

# df contains all the variables that were column headers of the .csv file.
# the "Date" dimension is the "index" dimension for the dataframe. The dates␣
↪are saved as "datetime" objects which know
# lots of useful things about time, like how to interpret minutes and hours,␣
↪etc.

# We can get a extra variables (DOY & HOUR) that will be helpful later
df1['HOUR'] = df1.index.hour
df1['DOY'] = df1.index.dayofyear
df1['TIME'] = df1.index.time

# Take a quick look at the first few entries - the pandas "head()" command␣
↪prints out the top of the dataframe that you just opened:
df1.head()

# "NaN" stands for "not a number", and is used in datasets to show where there␣
↪is no value for the variable at that time.
```

[13]:

```
                     K_in  K_out   L_in  L_out  AirT    RH  HOUR    DOY  \
Date
2010-07-10 00:10:00   0.0    0.0  383.0  403.2   NaN   NaN   0.0  191.0
2010-07-10 00:20:00   0.0    0.0  370.9  400.8   NaN   NaN   0.0  191.0
2010-07-10 00:30:00   0.0    0.0  363.1  399.1  19.3  70.2   0.0  191.0
2010-07-10 00:40:00   0.0    0.0  355.6  397.5   NaN   NaN   0.0  191.0
2010-07-10 00:50:00   0.0    0.0  357.3  397.4   NaN   NaN   0.0  191.0

                         TIME
Date
2010-07-10 00:10:00  00:10:00
2010-07-10 00:20:00  00:20:00
2010-07-10 00:30:00  00:30:00
2010-07-10 00:40:00  00:40:00
2010-07-10 00:50:00  00:50:00
```

1.4 Question 1:

[7]

(a) [3] Estimate the approximate surface albedo of the grass surface for that day. Justify your calculation of the albedo.

(b) [4] Plot the variation in surface albedo over the course of the day. Label all axes and lines, and include correct units if/where appropriate. Do you observe any diurnal variation of the albedo? **HINT: you can copy-paste the plotting code from Assignment 1 and modify it to plot albedo instead of radiative fluxes.**

(albedo = reflected / incident)

[14]:
```
avg4 = round(df1['K_in'].mean(),2)
avg5 = round(df1['K_out'].mean(),2)

albedo = avg5/avg4

print ('The approximate surface albedo of the grass surface for the day is ' +␣
 ↪str(albedo))
```

```
The approximate surface albedo of the grass surface for the day is
0.23669094759811315
```

Rubric:

(a) [1] for right approach / justification (albedo = reflected / incident), [1] for code, [1] for right answer

(b) [1] for generating a plot, [1] for labeling axes, [1] for the correct line, [1] for commeting on the diurnal variation

[15]:
```
df1['albedo'] = df1['K_out'] / df1['K_in']
```

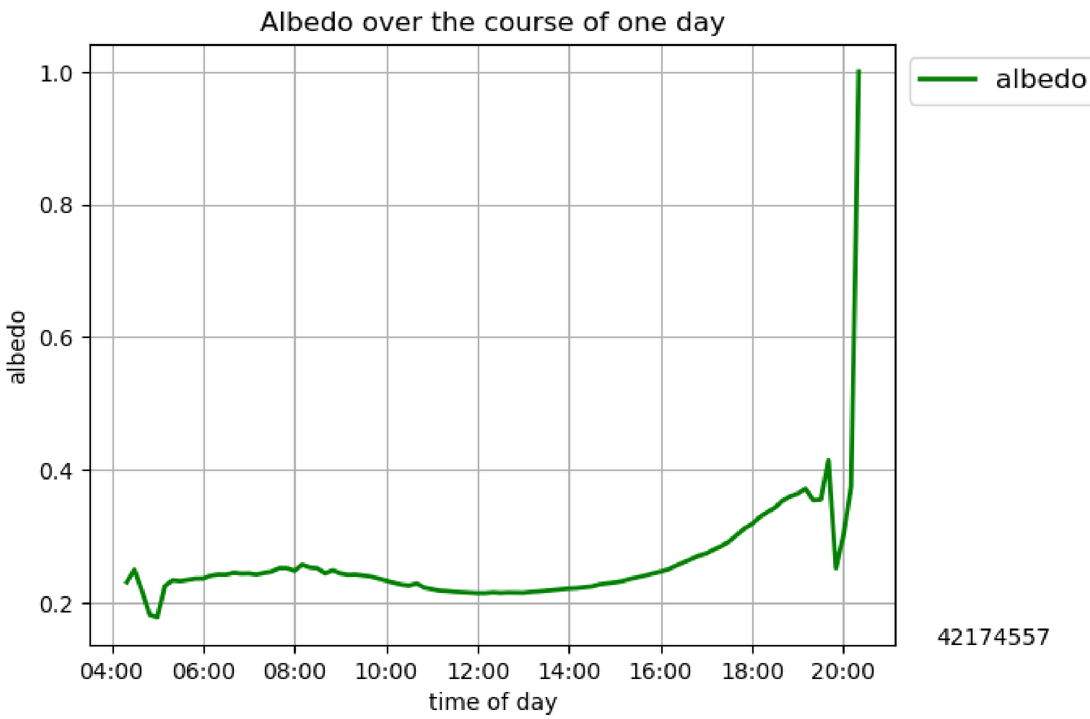
[16]:
```
plt.plot(df1.index,df1['albedo'],label='albedo',color='green',linewidth=2)

# make the plot prettier:
plt.grid()
plt.legend(fontsize=12,loc='upper left', bbox_to_anchor=(1., 1.))
plt.ylabel('albedo')
plt.xlabel('time of day')
plt.gca().xaxis.set_major_formatter(mdates.DateFormatter('%H:%M'))

plt.title('Albedo over the course of one day')

# add your student number
plt.text(1.05,0.0,'%1.0f'%42174557,
         fontsize=10,transform=plt.gca().transAxes)

plt.show()
plt.close()
```



"In most radiation transfer models, the diurnal variation of surface albedo is assumed to be symmetric and parabolic and forced by the diurnal variation of zenith angle. High values occur near sunrise and sunset, with the minima near solar noon." (Song 181)

There is diurnal variation during sunset at 20:00, where the albedo reaches 1.0. This is because during sunset and sunrise the angle of incoming solar radatation is skewed making albedo skewed as well.

1.5 Question 2

[7]

Look-up in a text book or scientific paper an estimate of the surface emissivity 0 of a short grass-surface; cite your source in your answer.

Using this value, calculate the true surface temperature T0 in degrees Celcius (i.e. considering that the surface is a grey body and reflects) at noon for the given day.

Hint: typical emissivities of vegetation are between 0.9-1. Always include units.

rubric:

[8] - 1 for plausible 0 value, 1 for citing your source, 2 for correct approach, 2 for showing work, 1 for correct answer; -0.5 for missing units.

 0 = 0.949 From Jin, M., & Liang, S. (2006). An improved land surface emissivity parameter for land surface models using Global Remote Sensing Observations. Journal of Climate, 19(12), 2867–2881. https://doi.org/10.1175/jcli3720.1

Eg = T^4 + (1-) Ldown Eg = Longwave up

[17]:
```
emissivity  = 0.949
o = 5.67 * 10**(-8)
longwaveup = 487.7
longwavedown = 378.5
T = ((longwaveup-(1-emissivity)*longwavedown)/(emissivity*o))**(1/4)
print ('The true surface temperature T0 is ' + str(T) +' K' + ' or 32.
 ↪300677309514526˚C')
```

```
The true surface temperature T0 is 305.4506773095145 K or 32.300677309514526˚C
```

1.6 Question 3

[8]

Find a way to calculate the 'apparent' radiative sky temperature (T_{sky}) in °C from the measured L↓ at noon ('apparent' means you should assume $\varepsilon_a = 1.0$). How would you interpret T_{sky}?

rubric:

[8] - 2 for approach, 2 for showing work, 2 for numerical answer (-0.5 per missing unit in answers), 2 for discussion

L↓ = 378.5
$\varepsilon_a = 1.0$

L↓ = T^4

[18]:
```
emissivity = 1
T = ((longwaveup-(1-emissivity)*longwavedown)/(emissivity*o))**(1/4)
print ('The ‘apparent’ radiative sky temperature is ' +str(T)+ ' or 31.
 ↪388654185772111305˚C.')
```

```
The ‘apparent’ radiative sky temperature is 304.5386541857721 or
31.388654185772111305˚C.
```

Tsky is where the longwave radiation reaches the atmosphere and is heating up the atmosphere to a certain temperature. Disregarding clouds, gasses and aerosols.

1.7 The remainder of the problem set uses a dataset of soil temperature observations

The data-set consists of 15-min averages of the following variables: four soil temperatures (T1, T2, T3, and T4) measured at depths of 5 cm, 10 cm, 20 cm and 50 cm, respectively, soil heat flux density Q_G from a soil heat flux plate installed at a depth of 7.5 cm, soil volumetric water content $_w$ measured using TDR at -7.5 cm, net all-wave radiation Q* measured 2 m above the surface, and sensible heat flux density in the atmosphere Q_H measured 2m above the surface. Use this data-set to answer all the following questions.

The soil at the climate station has been analyzed in the lab and the following values were determined: porosity is P = 0.57, bulk density of the dry soil is s = 1.13 Mg m—3. The soil organic mass fraction was determined 3.77 % (of total dry soil mass). Assume that those values apply to the entire vertical profile.

dataset name:

data20090324.xls

[19]:
```
# Import the data  - upload this file from Canvas and put it in the same folder␣
↪as your assignment.
data_file = 'data20090324.xls'


df2 = pd.read_excel(data_file)

# a few post processing steps:

# 1. Remove units from variable names & rename variables
names_and_units = list(df2.columns.values)
just_names = [x.split(" ",1)[0] for x in names_and_units]

# replace the column names with our new names that don't have units
df2.columns = just_names

df2.head()
```

[19]:

	Date	T_1	T_2	T_3	T_4	QG	qw	Q*	QH
0	2009-03-24 00:15:00	0.844	1.110	1.383	1.313	-1.88	0.366	-1.2	NaN
1	2009-03-24 00:30:00	0.822	1.112	1.372	1.307	-1.86	0.367	-1.5	-40.7
2	2009-03-24 00:45:00	0.817	1.089	1.358	1.316	-1.89	0.367	-2.1	NaN
3	2009-03-24 01:00:00	0.797	1.093	1.381	1.330	-1.98	0.367	-2.1	-16.3
4	2009-03-24 01:15:00	0.788	1.060	1.382	1.333	-2.12	0.368	-1.8	NaN

1.8 Question 4

[8]

Calculate the net warming/cooling of the soil over the 24 hours separately for the 5 cm, 10 cm, 20 cm and the 50 cm depth (i.e. the temperature change from midnight to midnight). Speculate what causes the warming or cooling.

Always include units.

rubric:

[8] - 2 for approach, 2 for showing work, 1ea for numerical answer, -0.5 per missing unit in answers

ΔT = Tfinal − Tinitial

ΔT5cm = 2.11 - 0.84 = 1.27 cm ΔT10cm = 2.52 - 1.11 = 1.41 cm ΔT20cm = 2.35 - 1.38 = 0.97 cm ΔT50cm = 1.32 - 1.31 = 0.01 cm

Solar radiation causes the soil to warm or cool. During the day, the soil absorbs heat from the sun.

Surface layers (5 cm and 10 cm) experience more rapid warming and cooling due to direct exposure to sunlight, while deeper layers (20 cm and 50 cm) warm more slowly. Vegetation also affects the soil as more plants = more shade and less direct exposure of solar radiation.

1.9 Question 5:

[14]

(a) [8] Calculate the daily average soil temperature for each of the four depths where temperatures are provided (T1 to T4).

(b) [6]Using those, determine the direction of the daily total QG in the soil layers from 5 - 10 cm, 10 - 20cm and 20 - 50cm?

Always include units.

rubric:

(a) [8] - 2 for approach, 2 for showing work, 1ea for numerical answer

(b) [6] - 2 for approach, 1 for showing work, 1ea for 3x direction of flux answer

-0.5 per missing unit.

[20]:
```
da5cm = round( df2['T_1'].mean(),2)
da10cm = round( df2['T_2'].mean(),2)
da20cm = round( df2['T_3'].mean(),2)
da50cm = round( df2['T_4'].mean(),2)
print ('Daily average soil temperature of 5 cm is ' + str(da5cm) + '˚C.')
print ('Daily average soil temperature of 10 cm is ' + str(da10cm) + '˚C.')
print ('Daily average soil temperature of 20 cm is ' + str(da20cm) + '˚C.')
print ('Daily average soil temperature of 50 cm is ' + str(da50cm) + '˚C.')
```

```
Daily average soil temperature of 5 cm is 2.7˚C.
Daily average soil temperature of 10 cm is 2.14˚C.
Daily average soil temperature of 20 cm is 1.58˚C.
Daily average soil temperature of 50 cm is 1.28˚C.
```

Based on these calculations, each layer that is deeper than the other is decreasing in temperature. So we can state that the direction of the daily total QG in all the soil layer ranges (5-10cm, 10-20cm, 20-50cm) are going downwards.

5-10 cm = 2.7 - 2.14 = 0.56 $^\circ$ C 10 - 20 cm = 2.14 - 1.58 = 0.56 $^\circ$ C 20 - 50 cm = 1.58 - 1.28 = 0.3 $^\circ$ C

1.10 Question 6:

[4]

Calculate the daily total of Q_G at 7.5 cm depth in MJ m−2 day−1 using the measured values from the soil heat flux plate. Compare the direction of Q_G to the direction of the heat flux obtained for the 5-10 cm layer in question 5.

Rubric: [1] for approach, [1] for showing your work, [1] for numerical answer, [1] for discussion. -0.5 per missing unit.

[21]:
```python
QGavg = df2['QG'].sum()
Joulesspersperm2 = 24*60*60*QGavg
Joulesspersperday = Joulesspersperm2*0.000001

print ('The daily total of QG at 7.5 cm depth is '+str(Joulesspersperday) + (' MJ / m^2 day.'))
```

```
The daily total of QG at 7.5 cm depth is 39.388895999999995 MJ / m^2 day.
```

The direction of the heat flux obtained for the 5-10 cm layer is downward/postive. Flux density of heat conducted QG is proportional to the temperature gradient which would state in a downward/postitve direction.

1.11 Question 7:

[7]

Estimate the thermal conductivity of the soil k at noon that day. Is k constant throughout the day?

Hint: use the temperature gradient between the 5 and 10 cm soil layers.

Rubric:

[2] for approach, [2] for showing work, [1] for numerical answer, [2] for discussion of variation in k throughout day. -0.5 for missing units.

$$Q_G = -k \frac{\partial T}{\partial z}$$

[27]:
```python
T5cm = 4.03
T5cminK = 277.18
T10cm = 1.86
T10cminK = 275.01
changeT =  T10cminK  - T5cminK
changez = 0.1 - 0.05
QG = 16.17
```

[28]:
```python
k = -(changez/changeT)*QG
```

Thermal conductivity of the soil k at noon that day is 0.37258064516128764 W/m K.

k is not constant throughout the day as it changes with temperature and the amount of water in the soil at that given time.

1.12 Question 8:

[5]

Calculate the heat capacity C of the soil using the lab analysis results (see text where the dataset is described above) and measured soil water content w.

Rubric: [2] for approach, [2] for showing work, [1] for answer; -0.5 for missing units.

$$C_s = C_m\theta_m + C_o\theta_o + C_w\theta_w + C_a\theta_a$$

$$P = \theta_a + \theta_w = 1 - \theta_g \qquad \theta_g = \theta_m + \theta_o \qquad \theta_a + \theta_w + \theta_g = 1$$

Cs = 2.1 * θm + 2.5 * θo + 4.18 * θw + 0 * θa Ca is very small relative to the other values of C, so it can be neglected.

P = 0.57 θw = 0.36 θa = 0.21 θg = 0.43 θo = 0.0377 * 0.43 = 0.016211 θm = 0.413789

[40]:
```
avg0w = 0.36
o = 0.016211
m =  0.413789
Cs = (2.1*m)+(2.5*o)+(4.18*avg0w)
print('The heat capacity C of the soil is '+str(Cs) + ' MJ/ m^3 K.')
```

```
The heat capacity C of the soil is 2.4142844 MJ/ m^3 K.
```

1.13 Question 9:

[?]

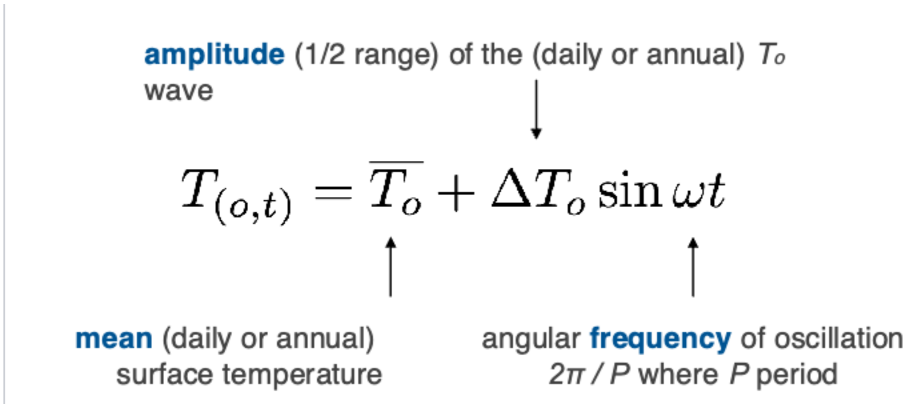
With C from question 8, calculate the depths where you expect the amplitude of the diurnal and yearly waves to drop below 5% of the amplitude of the sinusoidal surface temperature wave.

rubric: [2] approach, [2] showing work, [2] numerical answer ([1] each diurnal/yearly); -0.5 per missing units.

$$D = \sqrt{\frac{2\kappa}{\omega}} = \sqrt{\frac{\kappa P}{\pi}}$$

At 3D the amplitude of the diurnal and yearly waves to drop below 5% of the amplitude of the sinusoidal surface temperature wave.

$= k/C \quad = 0.37/2.9 \quad = 0.13\ m^2/s$



Find Depth for damping depth and amplitude for diurnal and yearly waves as well as sinusoidal wave

[32]:
```
annualperiod = 365*24*60*60
dirunalperiod = 24*60*60
k = 0.13

Dd = (((dirunalperiod*k)/ np.pi )**(1/2))/3
Da = (((annualperiod*k)/np.pi)**(1/2))/3

print ('The depth at which the amplitude of the diurnal waveto drop below 5% of the amplitude of the sinusoidal surface temperature wave is '+str(Dd)+ ' m.')
print ('The depth at which the amplitude of the annual wave to drop below 5% of the amplitude of the sinusoidal surface temperature wave is '+str(Da)+ ' m.')
annualperiod
```

```
The depth at which the amplitude of the diurnal waveto drop below 5% of the
amplitude of the sinusoidal surface temperature wave is 19.931149940667517 m.
The depth at which the amplitude of the annual wave to drop below 5% of the
amplitude of the sinusoidal surface temperature wave is 380.78408495424327 m.
```

[32]: 31536000

1.14 Question 10

[4]

The Bowen ratio describes the ratio between the sensible and latent heat flux densities directed into the atmosphere, i.e. $= QH/QE$. Calculate from the available data for noon that day. Neglect the energy use for photosynthesis.

rubric: [2] for approach, [1] for showing work, [1] for answer

$$Q^* = Q_H + Q_E + Q_G$$

[33]:
```
QH = 49.3
Qnet = 269.5
QG = 16.17

QE = Qnet-QH-QG
Bowen = QH/QE

print ('The Bowen ratio for noon is ' + str(Bowen)+'.')
```

```
The Bowen ratio for noon is 0.2416311326765672.
```